Organic Chem 10.4 – Alcohols

IB Chemistry

Topic 10 – Organic

10.4 – Alcohol Reactions – 2hrs

- 10.4.1 Describe, using equations, the complete combustion of alcohols. (2)
- 10.4.2 Describe, using equations, the oxidation reactions of alcohols. (2)
- 10.4.3 Determine the products formed by the oxidation of primary and secondary alcohols. (3)

Complete combustion of alcohol

10.4.1 Describe, using equations, the complete combustion of alcohols. (2)

- The general formula for alcohols:
  - $C_nH_{2n+1}OH$
- Exothermic, used as fuels
- Amount of energy released increases as you go up the homologous series

Combustion Equation	ΔH_c^θ	CO_2:OH ratio
$2CH_3OH + 3O_2 \rightarrow 2CO_2 + 4H_2O$	-726 kJ/mol	1:1
$2C_2H_5OH + 5O_2 \rightarrow 4CO_2 + 6H_2O$	-1376 kJ/mol	2:1
$2C_5H_{11}OH + 15O_2 \rightarrow 10CO_2 + 12H_2O$	-3330 kJ/mol	5:1

Enthalpy Increase

“Gasahols as fuels”

- Countries such as Brazil combine ethanol with gasoline to produce fuel for cars known as **gasahol**.
  - In the midwest of the United States you may be able to find some as well
  - Countries become less dependent on oil
- But, the growth of corn and other materials used for ethanol use large amounts of energy to produce and weight for weight it’s not as efficient as gasoline

Try calculating what 1gram of each will produce if $\Delta H_c(C_8H_{18}) = -5512\ kJ\ mol^{-1}$

Alcohol vs. Alkane

Equation	Molar production	Gram production
$2C_2H_5OH + 3/2O_2 \rightarrow 2CO_2 + 3H_2O$	-1376 kJ/mol	29.8 kJ/g
$2C_8H_{18} + 25O_2 \rightarrow 16CO_2 + 18H_2O$	-5512 kJ/mol	48.4 kJ/g

- Ethanol vs. Octane comparison shows that one gram of octane produces 62% more energy than the same mass of ethanol.

10.4 Properties of Alcohols

- Contain the hydroxyl (-OH) group
- Formula $C_nH_{2n+1}OH$
- Polar group → increases solubility of compound
- Most common is ethanol, C_2H_5OH
- Can form hydrogen bonds with water through the hydroxyl group and therefore have higher boiling points than their alkane equivalents.

Oxidation Reactions of alcohols

10.4.2 Describe, using equations, the oxidation reactions of alcohols. (2)

- Alcohol functional group is capable of being oxidized
- Products depend on whether the alcohol is primary, secondary, or tertiary
- Common laboratory oxidizing agent is potassium dichromate (VI). This is a bright orange solution.
- When reaction mixture is heated a color change takes place as Cr(VI) → Cr (III) which is green.
- Alcohol is oxidized (loss of electrons – Topic 09)
- [O] is known as the oxidizing agent, when in addition with 2 H forms water (H_2O)

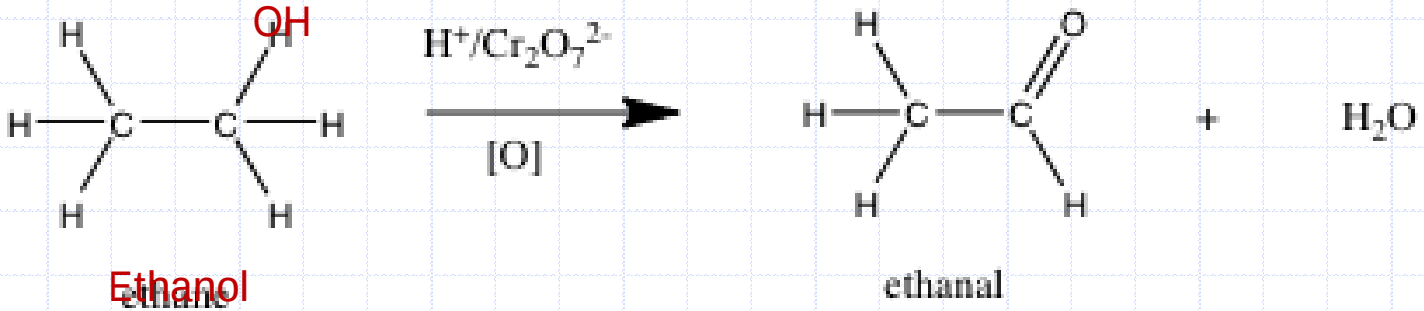
Primary, Seconary, Tertiary

10.4.3 Determine the products formed by the oxidation of primary and secondary alcohols. (3)

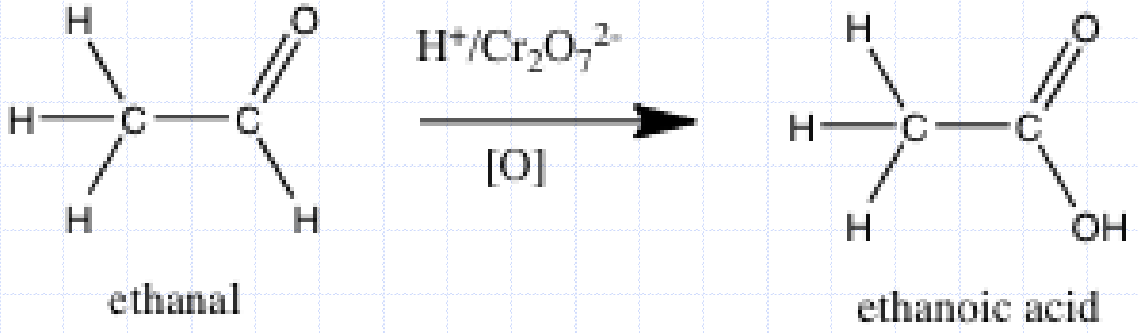
- **Primary**, two steps
- **Secondary**, one step
- **Tertiary**, no steps!

Oxidation of a Primary Alcohol

- Primary Alcohols are oxidized in a two-step process when under reflux (continuation)
  - First to form an **aldehyde**



  - Second to form a **carboxylic acid**

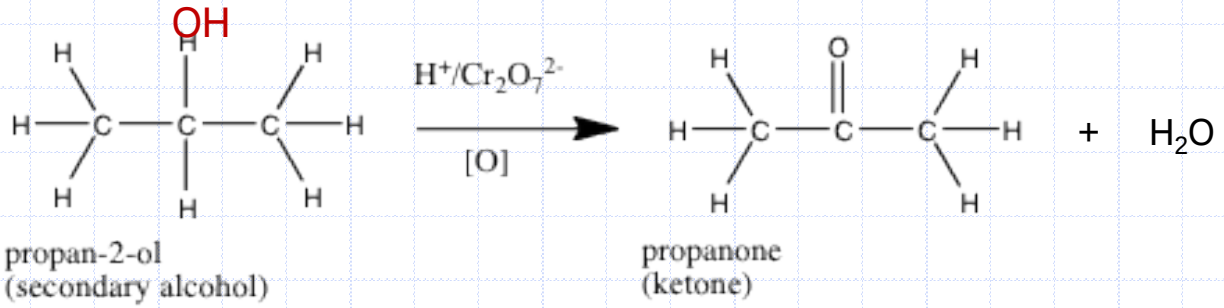


Isolating a desired product

- In order to isolate products:
  - If the **aldehyde** (product of first step) **is desired**, it can be removed by distillation as aldahydes have lower B.P.'s than alcohols and carboxylic acids (which both have h-bonding)
  - If **carboxylic acid is desired**, the reaction can be in reflux where an excess of the oxidizing agent is present for a prolonged period of time

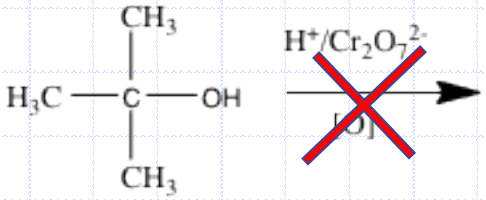
Oxidation of a Secondary Alcohol

- Secondary alcohols contain only a single hydrogen attached to the OH-containing carbon.
- Only one product is possible in this case, a ketone and is completed in one step



Oxidation of a Tertiary Alcohol

- Tertiary alcohols will not react with the oxidizer as they do not contain a hydrogen attached to the OH-containing carbon.



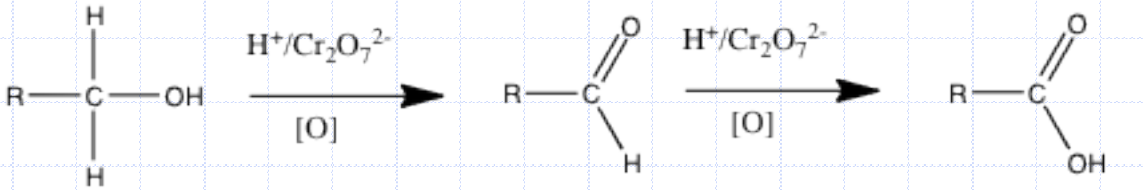
(tertiary alcohol)

no oxidation possible as
no hydrogen atom on carbon
atom bonded to the alcohol group

Primary, Seconary, Tertiary

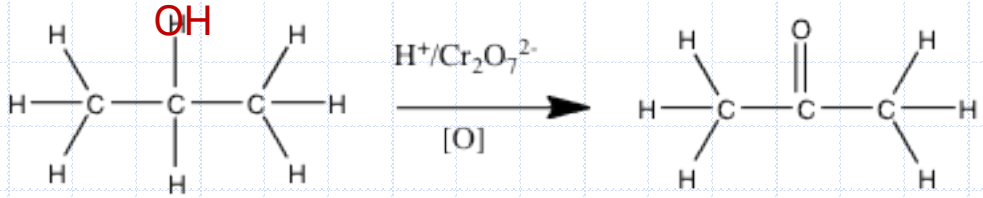
10.4.3 Determine the products formed by the oxidation of primary and secondary alcohols. (3)

- **Primary**, two steps



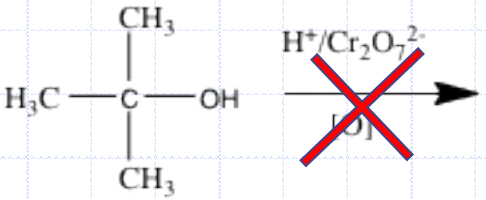
primary alcohol — aldehyde — carboxylic acid

- **Secondary**, one step



propan-2-ol (secondary alcohol) — propanone (ketone)

- **Tertiary**, no steps!



(tertiary alcohol)

no oxidation possible as
no hydrogen atom on carbon
atom bonded to the alcohol group